Research Reports

Effects of Application of Various Reduced-risk Pesticides to Tomato, with Notes on Control of Greenhouse Whitefly

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SUMMARY. Experiments conducted in greenhouse and field environments investigated the acute and chronic phytotoxic effects of several household and commercially available

soaps, detergents, and oils applied to tomato (*Lycopersicon esculentum* Mill.). In addition, the effect of these treatments on greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), was investigated. In the greenhouse experiments, the number of whiteflies observed was negatively correlated with phytotoxicity (i.e., higher phytotoxicity = fewer whiteflies). Ivory Clear detergent at two rates of application (0.5% or 2.0%) caused the greatest phytotoxicity to seedling tomato plants. Addition of vegetable oils to a 0.5% Ivory Clear detergent solution did not affect phytotoxicity to the plants. While commercially available insecticidal soap (M-Pede) and a neem seed extract (Margosan-O) had little phytotoxicity, they provided only a slight reduction of whitefly populations. A field experiment conducted in the absence of insect pressure showed phytotoxic effects to tomato plants as a result of continued treatment with New Ivory detergent. Significantly lower yield from this treatment resulted from reduced flower and/or fruit production. None of the other compounds in the field experiment significantly affected the yield of tomato plants.

Crop consultants, extension professionals and wholesale/retail nursery professionals are frequently requested to recommend alternatives to traditional pesticides for insect control. Among the strategies commonly discussed in plant protection literature are soap and/or oil sprays. Soaps and detergents disrupt insect membranes or may remove the protective waxes covering an insect (Cranshaw, 1996). Oils work by leaving a film after application and smothering an insect (Davidson et al., 1991), although some membrane disruption may also result from their use. Soaps

and oils are recommended for the control of a variety of insect and mite pests. In addition, household soaps, detergents, and oils are popular with homeowners because of their availability, ease of use, and low cost (Butler and Henneberry, 1990).

Examinations into the utility of soaps, detergents, and oils for vegetable insect pest control have been performed. Butler and Henneberry (1990) used cooking oil and soap mixtures to control whiteflies, aphids, and spider mites on an assortment of garden vegetables. Soaps, detergents, and oils have also been used for insect species which are considered difficult to control with traditional synthetic pesticides. Examples of this are control of sweetpotato whitefly (*Bemisia tabaci* Gennadius) and silverleaf whitefly (*Bemisia argentifolii* Bellows and Perring) in studies by Butler et al. (1993) and Larew and Locke (1990). More recently, Liu and Stansly (1995) and Vavrina et al. (1995) have reported control studies of whiteflies on tomato.

Concerns about phytotoxicity have always surrounded soaps, detergents, and oils. Acute symptoms that are sometimes observed with the applications of these products may include: leaf burning, leaf spotting, leaf curling or other distortions, and partial to full defoliation of the treated plant. Vavrina (1992) and Butler et al. (1993) have observed such effects from these treatments on tomato.

Far less common are studies that track more subtle effects on plant growth and development. These effects may not be as obvious as the symptoms described above, but may still affect plant growth, yield, and quality. A season-long study conducted by Vavrina et al. (1995) tracked the effects of repeated detergent applications on tomato plant yield. However, this study did not concurrently use commercially available insecticidal soaps or oils to see if similar phytotoxic effects were present with these treatments. Furthermore, the presence of large numbers of whiteflies on plants used in their study made it difficult to discern whether the yield effects observed were due directly to phytotoxicity, or involved insect-induced effects as well as chemical damage.

This study has two primary objectives. First, to screen a wide variety of commonly recommended reduced-risk

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pesticides (with emphasis on household detergent and vegetable oil treatments) for their efficacy and potential phytotoxicity when used to control greenhouse whitefly (*Trialeurodes vaporariorum*) on tomato plants. Second, to assess acute phytotoxicity and the long-term effects on tomato plant productivity from the use of repeat applications of test compounds, under outdoor field conditions.

Materials and methods

GREENHOUSE TRIALS (1995). Two experiments were performed on seedling (10-leaf stage) tomatoes, both conducted in a greenhouse located on the campus of Colorado State University. The experimental design in both studies was a randomized complete block with six replications. Plants in both experiments were arranged in blocks by size and vigor. In both experiments, cultivar choice was determined by seed availability. A water spray was used as a control treatment in both experiments.

In the first experiment, tomato seedlings ('San Marzano') recently transplanted to 6-inch (15.25-cm) pots were initially treated on 23 May 1995. Treatments used in the experiment were two rates (2.0% and 0.5% solutions) of an over-the-counter household detergent (Ivory Clear detergent,

Proctor and Gamble Corp., Cincinnati, Ohio) and a mixture of detergent with a vegetable oil (0.5% Ivory clear detergent plus 2.0% Wesson corn oil, Wesson sunflower oil, or CanoLite canola oil (Hunt-Wesson, Inc., Fullerton, Calif.; Calgene, Inc., Des Plaines, Ill.). Two commercially available horticultural oils (Sunspray 6E, Zeneca Ag Products, Wilmington, Del.; Margosan-O, Vikwood Ltd., Sheboygan, Wis.) and an insecticidal soap (M-Pede, Mycogen Corp., San Diego, Calif.) were used as standards in the experiment at rates specified in Table 1. A homeopathic remedy (Crabapple Remedy and Rescue Remedy, Ellon, Woodmere, N.Y.) was also included in the screening to test for whitefly control and phytotoxic effects.

All treatments were applied using a hand-operated pump mist sprayer and applied to the point of runoff. The homeopathic remedy treatment was applied in accordance with the dose instructions and recommended uses specified in Scheffer (1988), by treating the plants when signs of stress appeared with 10 drops of each remedy diluted in 1 qt of water. A reapplication of all treatments was made on 29 May 1995 (6 d after the first treatment (6 DAT)), when the first phytotoxicity survey was performed.

Phytotoxicity and insect counts were made on three dates—29 to 31 May (6 and 8 DAT), 8 June (16 DAT), and 16 June 1995 (24 DAT). Phytotoxicity was determined by whole plant evaluations. Phytotoxic symptoms scored were marginal and whole-leaf necrosis, as well as leaf curling, leaf bronzing, and leaf distortion. Phytotoxicity was assessed by a visual estimate, using a six-point rating scale: 0 = no phytotoxicity observed on plant, 1 = 1% to 20% of entire plant surface displaying phytotoxic symptoms, 2 = 21% to 40% of entire plant surface displaying phytotoxic symptoms, 3 = 41% to 60% of entire plant surface displaying phytotoxic symptoms, 4 = 61% to 80% of entire plant surface displaying phytotoxic symptoms and 5 = 81% to 100% of entire plant surface displaying phytotoxic symptoms. Two researchers each estimated phytotoxicity individually and their results were averaged together for the purposes of statistical analysis. Greenhouse whitefly control was estimated on each sample date by examining the fifth most fully expanded leaflet from the plant. The number of instar I–IV nymphs present on this leaflet for each treatment was counted using a dissecting scope at 40× normal magnification.

The second experiment used the

Table 1. Phytotoxicity ratings using a six point rating scale and number of whitefly nymphs and pupae observed on tomato plants with the use of several reduced-risk compounds for insect control, 1995.

Treatment	Rate	Phytotoxicity rating ^a			Whitefly nymphs and pupae/leaflet ^b (mean no.)		
		29 May (6 DAT) ^c	8 June (16 DAT)	16 June (24 DAT)	31 May (8 DAT)	8 June (16 DAT)	16 June (24 DAT)
Ivory Clear detergent	2% solution	4.5 a ^w	4.6 a	4.7 a	52.8 a	1.8 a	17.0 a
	0.5% solution	3.1 b	2.8 b	2.5 b	79.2 ab	47.2 a	56.2 ab
Wesson corn oil + Ivory Clear detergent	2% solution						
	0.5% solution	2.8 bc	3.1 b	2.4 b	20.7 a	4.2 a	77.3 ab
CanoLite canola oil + Ivory Clear detergent	2% solution						
	0.5% solution	3.0 b	3.6 b	3.3 b	29.8 a	2.3 a	28.3 a
Sunspray horticultural oil	2% solution	2.8 bc	3.3 b	3.1 b	44.8 a	14.0 a	44.5 a
	0.5% solution	1.7 bc	2.9 b	2.6 b	36.2 a	19.7 a	14.2 a
Margosan-O (neem oil)	0.67% solution	1.3 bc	1.4 c	1.5 c	155.7 bc	58.3 a	112.3 abc
M-Pede insecticidal soap	2% solution	1.5 bc	1.6 c	1.4 c	80.3 ab	53.7 a	104.2 abc
Rescue Remedy + Crabapple (Homeopathic) Remedy	10 drops/qt	1.0 c	1.5 c	1.1 c	86.3 ab	170.5 b	180.3 c
Water check		1.2 c	1.2 c	1.6 c	174.8 c	204.8 b	166.7 bc

^aNumber of instar I–IV nymphs on fifth fully expanded leaflet on each sampling date.

^bPhytotoxicity rating is based on a six point scale where 0 = no phytotoxicity, 1 = 1% to 20% of plant displaying phytotoxic symptoms, 2 = 21% to 40% of plant displaying phytotoxic symptoms, 3 = 41% to 60% of plant displaying phytotoxic symptoms, 4 = 61% to 80% of plant displaying phytotoxic symptoms and 5 = 81% to 100% of plant displaying phytotoxic symptoms.

^cDAT = days after initial treatment application. A single reapplication of all treatments was made 6 DAT (on 29 May).

^wMeans followed by the same letter are not significantly different by the Student-Neuman-Keuls procedure ($\alpha = 0.05$).

same design and evaluation techniques. Changes included the use of a different tomato cultivar ('Rutgers') and only a single treatment application (13 June 1995) and evaluation (24 or 27 June 1995) dates. Treatments in this experiment were handsoaps [Ivory Liquid handsoap and Softsoap Original handsoap, Colgate-Palmolive Co., New York), dishwashing detergents (Ivory Clear detergent, Dawn dishwashing detergent, and Lemon Joy dishwashing detergent (all manufactured by Proctor and Gamble Co.)], and a commercially available insecticidal soap standard (M-Pede). All compounds were applied as 2% solutions using the same methodology as the first greenhouse experiment.

FIELD EXPERIMENT (1996). Field trials were conducted at the Colorado State University Horticultural Research Center, Ft. Collins. Tomato plants ('Roma') were transplanted 7 May to a single-row 30-inch (76-cm) bed. In-row spacing was 36-inch (91-cm), and each experimental unit consisted of four plants. Plot design was a randomized complete block design with four replications. Applications were made weekly for ten weeks, initiated on 16 June 1996. Treatments were two commercial horticultural oils (SunSpray and Margosan-O), an insecticidal soap (M-Pede), a garlic repellent (Guardian), and an over-the-counter detergent in an updated formulation (New Ivory Clear detergent). All solutions were applied until point of run off. For the first four application dates, ≈ 1 fl oz (30 mL) of solution was applied to each plant. Due to an increase in plant canopy, approximately 2 fl oz (60 mL)

of solution per plant was applied for the remainder of the experiment.

Fruit were harvested weekly starting on 16 August 1996, for 6 weeks. Ripe fruit was collected from each plot and weighed individually in the lab. On 24 Sept., phytotoxicity in all treatments was estimated by visual observation. A percentage of damaged foliage for each plant was recorded, then averaged across an entire experimental unit. No whiteflies were observed on the plants utilized in this study during the course of the experiment and data for their populations were not recorded.

STATISTICAL ANALYSIS. All statistical analyses in the study were performed with the SAS for Windows ver. 6.10 software (SAS Inc., Cary, N.C.) and used PROC GLM syntax. Multiple comparisons of appropriate means were accomplished with the Student-Neuman-Keuls procedure ($\alpha = 0.05$).

Results and discussion

GREENHOUSE TRIALS. In the first experiment, plants treated with the highest rate (2.0%) of Ivory Clear detergent showed the greatest phytotoxicity on all three sample dates (Table 1). On the first sample date, Ivory Clear at the 0.5% rate and a spray of sunflower oil + Ivory Clear also had significantly higher phytotoxicity ratings than the control (Table 1). On the second and third sample date, only Margosan-O, M-Pede and the homeopathic remedy treatment did not have significantly different phytotoxicity ratings from control plants. Among plants receiving 0.5% Ivory Clear detergent, the addition of a vegetable oil (whether sunflower, canola, or corn

oil) did not significantly affect phytotoxicity ratings (Table 1).

On the first sample date, all compounds tested except for Margosan-O had significantly fewer whitefly nymphs compared to the control treatment (Table 1). On the second sample date, all treatments except the homeopathic remedy had a significantly lower number of whitefly nymphs observed overall (Table 1). At the final sample date, SunSpray Oil, Wesson sunflower oil + 0.5% Ivory Clear, Canolite canola oil + 0.5% Ivory Clear, and Ivory Clear detergent at the highest rate of use (2.0%) had significantly fewer whitefly nymphs observed per leaf compared to the control treatment (Table 1). Butler et al. (1993) had previously suggested that 0.5% solutions of detergents were effective for whitefly control.

In general, the number of whiteflies observed were negatively correlated with phytotoxicity among tested treatments (i.e. higher phytotoxicity = a lower number of whiteflies observed). The correlation values for the first greenhouse experiment were as follows: $r = -0.32$, $p < 0.0114$ for the 29 and 31 May 1995 sample; $r = -0.64$, $p < 0.0001$ for the 8 June 1995 sample; and $r = -0.54$, $p < 0.0001$ for the 16 June 1995 sample.

Results from the second greenhouse experiment were similar to the first. For phytotoxicity ratings, only M-Pede insecticidal soap and Softsoap hand soap were not significantly different from the control for phytotoxicity ratings (Table 2). Ivory Clear detergent and Lemon Joy dishwashing detergent were the only treatments that significantly reduced the number of

Table 2. Phytotoxicity rating and number of whiteflies per leaf of several over-the-counter soaps and detergents (Expt. 2).

Treatment	Rate	Phytotoxicity rating ^y	Whitefly nymphs and pupae/leaflet ^z
		24 June 1995 (11 DAT) ^x	27 June 1995 (14 DAT)
Ivory Clear detergent	2% solution	4.6 a ^w	26.5 a
Dawn dishwashing detergent	2% solution	4.5 a	91.3 bc
Lemon Joy dishwashing detergent	2% solution	3.8 ab	27.2 a
Ivory liquid handsoap	2% solution	3.4 b	157.5 bc
M-Pede insecticidal soap	2% solution	1.4 c	143.2 bc
Softsoap original handsoap	2% solution	1.3 c	215.2 bc
Water check		1.2 c	374.3 c

^zNumber of instar I-IV nymphs on fifth fully expanded leaflet on each sampling date.

^yPhytotoxicity rating is based on a six point scale where 0 = no phytotoxicity, 1 = 1% to 20% of plant displaying phytotoxic symptoms, 2 = 21% to 40% of plant displaying phytotoxic symptoms, 3 = 41% to 60% of plant displaying phytotoxic symptoms, 4 = 61% to 80% of plant displaying phytotoxic symptoms and 5 = 81% to 100% of plant displaying phytotoxic symptoms.

^xDAT = days after initial treatment application.

^wMeans followed by the same letter are not significantly different by the Student-Neuman-Keuls procedure ($\alpha = 0.05$).

Fig. 1. Average yield per plant over six different harvest dates for tomato plants treated with reduced-risk compounds grown outdoors in Ft. Collins, Colo., 1996. Bars at each data point are $\pm$ standard error.

whitefly nymphs compared to the control (Table 2). However, these two treatments both had significantly higher phytotoxicity ratings compared to control plants (Table 2). The second greenhouse experiment yielded a correlation value of $r = -0.57$, $p < 0.0001$ when the number of whiteflies were compared to phytotoxicity ratings for the 24 and 27 June 1995 sample (11 and 14 DAT, respectively).

Different tomato cultivars were used for the each of the experiments. Cultivars will often vary in their susceptibility to insect pest pressure and in their sensitivity to chemicals. Thus, the results obtained from each trial should be assessed independently.

FIELD EVALUATION. Throughout the course of the experiment, insect pressure observed at the site was very low and was not quantified. Rude and Clark (1985) suggested that greenhouse whitefly populations seldom build up to damaging levels in tomato fields. Cranshaw (1992) stated that greenhouse whitefly could not survive freezing temperatures in the northern U.S. and died out annually in unprotected locations.

In contrast to the greenhouse trial, no significant differences in foliar injury symptoms were observed among treatments (data not shown). All plants in the experiment were grown in the same field and arranged in blocks to compensate for possible differences due to weather conditions and soil fertility. Over all dates, the block effect was not significant ($F = 1.47$, $P = 0.2631$ for yield; $F = 0.95$, $P = 0.4400$ for mean fruit weight; $F = 0.74$, $P = 0.5427$ for fruit number) for individual test vari-

ables. As a result, differences in measured plant variables (fruit yield, weight, and number) reflect the effects of the applied treatments alone.

Plants treated with New Ivory detergent had the lowest yields on each sample date, although this effect was not significant (Fig. 1). In addition, New Ivory was the only treatment that showed an overall yield reduction when total harvest yields were accumulated (Table 3). This result corresponds to that of Vavrina et al. (1995), who observed a yield reduction from the use of a laundry detergent. No significant differences between treatments in mean fruit weight was observed on any individual harvest date or overall (Table 3, Fig. 2).

Plants treated with New Ivory detergent produced significantly fewer fruit per plant over all six harvest dates (Table 3). All other treatments had relatively similar values for the number of fruit produced per plant (Fig. 3,

Table 3. Overall harvest data for 1996 field evaluation of reduced-risk compounds for insect control on tomato; means and totals of six harvest dates between 16 Aug. and 23 Sept. 1996.

Treatment	Rate	Overall yield/plot ^z (kg)	Mean fruit wt ^y (g)	Fruit/plot ^x (no.)
SunSpray horticultural oil	2.0 % Solution	12.52 a ^w	41.4 a $\pm$ 9.34	300.0 a
Margosan-O (neem oil)	0.67 % Solution	12.43 a	40.9 a $\pm$ 10.01	301.5 a
M-pede (insecticidal soap)	2.0 % Solution	11.99 a	41.8 a $\pm$ 5.17	299.5 a
Guardian (garlic water)	2.0 % Solution	11.06 a	39.5 a $\pm$ 13.24	293.5 a
Untreated control		9.95 a	35.6 a $\pm$ 13.45	264.5 a
New Ivory Clear detergent	2.0 % Solution	6.15 b	41.4 a $\pm$ 10.82	133.3 b

^zOverall yield per four plants for each plot; 1 kg = 2.2 lb.

^yMean fruit weight for each treatment over all dates; 100 g = 3.53 oz.

^xTotal number of fruit harvested per four plants summed over all dates. Average of four replications.

^wMeans followed by the same letter are not significantly different by the Student-Neuman-Keuls procedure ($\alpha = 0.05$).

Fig. 2. Number of fruit harvested per plant on each of six harvest dates for plants treated with reduced-risk compounds and grown outdoors in Ft. Collins, Colo., 1996. Bars at each data point are $\pm$ standard error.

Table 3). It is this reduction in fruit production that appears to be the most important factor contributing to the reduced yield observed from the use of New Ivory detergent.

In the greenhouse screenings, no treatment significantly reduced whitefly populations beyond one week after application without showing some acute phytotoxic effects. However, there was a range in plant injury symptoms. Plants treated with Ivory Clear detergent at either rate (0.5% or 2.0%) produced the greatest injury. Other household detergents showed increased phytotoxicity compared to a commercial insecticidal soap (M-Pede) and a neem seed oil extract (Margosan-O). However, these compounds also gave variable control of whiteflies. Whitefly numbers tended to be negatively correlated with phytotoxicity, i.e., whiteflies were best controlled by treatments that concurrently damaged the plants. These results reinforce the idea that while some household detergents may be effective for whitefly control, excessive plant damage may result from their use.

In field trials, use of New Ivory detergent at a 2.0% rate, while not producing symptoms of acute phytotoxicity to plants when applied weekly, resulted in reduced yield. Fewer overall fruit were produced, which suggests an effect on either flower produc-

tion and/or fruit set. No differences in fruit weight were observed between treatments.

We feel that based on the data presented here, certain reduced-risk pesticides may show promise for use in greenhouse or field tomato production. Margosan-O (neem oil) and M-Pede (insecticidal soap) may control whitefly infestations when used weekly, without increased phytotoxicity to target plants. However, commonly available handsoaps, soaps, detergents, oils and mixtures of these compounds may not be suitable for this purpose, because of the acute or chronic phytotoxicity which may result from their use.

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